Thirty-year Wild Yak (*Bos mutus*) Management Plan for the Chang Tang Reserve, China

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Executive Summary

Wild yaks (*Bos mutus*) are the largest of thirteen ungulate species existing on the Tibetan Plateau in China. They are non-selective grazers and ruminants, which allows them to travel in herds of up to thousands of individuals and survive on relatively low-quality forage. Conservation issues of primary concern include resource competition with domestic ungulates, hybridization, poaching, trading, and the potential impacts of climate change (i.e. lower average snowfall and longer ice-free period). The shifting climate allows pastoralists to establish permanent residences and keep larger livestock herds, which reduces available habitat for wild yaks. This management plan aims to restore wild yak populations within the Chang Tang Reserve to the 1995 estimate of 15,000 mature individuals to allow local subsistence culture to proceed. Objectives to reach this goal include increasing the population of annually fertile females by 50% in fifteen years, increasing connectivity between the Reserve and other fragmented portions of wild yaks' distribution in China by 25% within ten years, and increasing landowner cooperation in wild yak conservation efforts by at least 75% within ten years. To increase the population of annually fertile females, at least five peer-reviewed articles focused on population dynamics and stage-based resource requirements will be published. These will require aerial surveys and fecal analyses. Furthermore, a mixture of optimally nutritious food plants will be planted in high elevation plots. Corridors with suitable habitat will be established between existing fragments to increase habitat connectivity. Surveying locals will help managers to identify uncertainties and to understand public awareness and perceptions of conservation need. Educational forums with supplementary materials will be provided to ensure locals are equipped to cooperate and to mitigate potential management issues, such as domestic-wildlife interaction. Locals of all ages will be provided education to establish positive perspectives of wild yaks and management practices, thus increasing cooperation. The management actions could increase yak populations above the Reserve's carrying capacity (~85,000) but allowing subsistence use will keep populations below this threshold.

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INTRODUCTION

Wild yaks (*Bos mutus*) are listed as vulnerable on the International Union for Conservation of Nature (IUCN) Red List, which has changed from the 1986-1994 listings as endangered (Buzzard and Berger 2016). The current classification is due to persisting and worsening threats, mainly imposed by the increasing human population and ease of access to previously inhospitable wild yak habitat (Berger et al. 2014). Major threats to the species include human disturbance, habitat reduction, competition with domestic ungulates, hybridization, poaching, and trading (Buzzard and Berger 2016). Currently, wild yaks only inhabit mountainous, alpine meadows from 4500-6100m elevation in China and India (Leslie and Schaller 2009). Their largest, unfragmented range lies within the Chang Tang Reserve on the Tibetan Plateau, but they also inhabit several other large nature reserves in China (Buzzard and Berger 2016). Habitat reduction and poaching are estimated to cause a further 10% decline in wild yak populations over the next 30 years (Buzzard and Berger 2016). However, more data need to be collected to thoroughly understand wild yak reproduction, survival, space use, and threats to the species so that optimal management can be implemented (Buzzard and Berger 2016).

Historically, wild yaks coexisted with pastoralists within their remote habitat and were used sustainably as pack animals, sources of clothing, fuel, food, milk, and other material resources (Tsering et al. 2006). The land was minimally populated because there were few access roads and harsh weather made living at higher elevation difficult, especially through the winter and spring (Harris et al. 1999). However, as climate change effects diminish the total area and duration of snow and ice cover in the Himalayas, higher elevation yak habitat is becoming suitable pasture for domestic herds (Aryal et al. 2014) and humans are establishing permanent residence (Schaller and Wulin 1995). Thus, wild yak habitat has been reduced by 50% and almost all remaining individuals exist on one large tract of land (Schaller and Wulin 1995).

Precise population estimates are difficult to obtain because wild yaks quickly flee from grazing territory if disturbed by humans, even from as far as one kilometer away (Harris 2007). Thus, the exact degree to which humans are impacting population sizes and distribution is unknown (Harris 2007). Resource partitioning between wild ungulates on the Tibetan Plateau is being disrupted by more frequent and persistent introduction of larger domestic herds (Fox et al. 2004). The expansion of pastoralists onto larger portions of wild yak habitat has led to resource competition between wild and domestic ungulates, displacement of wild yaks onto less suitable habitat, increased instances of poaching, and hybridization (Scaller and Wulin 1995, Buzzard and Berger 2016).

NATURAL HISTORY

Species Identification

Wild yaks are completely black or sometimes brown, except small gray patches on their muzzles (Fig. 1; Schaller 1998). However, approximately 2% of the global population, all within the Aru Basin, have a golden-haired mutation (Leslie and Schaller 2009). Yaks are large-bodied (350-1,000kg); males are 35% heavier than females and wild yaks are 63% heavier than domestic yaks on average (Leslie and Schaller 2009). Shoulder heights are between 175–203cm (adult males) and 137–156cm (adult females) (Leslie and Schaller 2009). Yaks have one conspicuous hump posterior to their short neck (Schaller 1998). Additionally, they have dense wool undercoats and coarse guard hairs with longer, draping hairs on their flanks, chest, and thighs (Fig. 1), which may reach the ground (>70cm) (Schaller 1998). Young (<6 months) are covered in dense down hairs, rather than guard hairs (Leslie and Schaller 2009). Yaks have long tails with longer hairs (up to 107cm) at the distal end (Fig. 1). Their tail can be moved horizontally or raised vertically during confrontation (Schaller 1998). Males and females both have relatively large horns (15-20cm diameter, 65-85cm length), but the males' horns are longer and curve more outward and forward (Fig. 1), while females' grow upward (Wiener et al. 2003).

Figure 1. Adult male wild yak (*Bos mutus*) with dark brown, long hair on its chest, flanks, thighs, and tail and curved horns.

Yaks have various morphological and physiological adaptations that allow persistence in cold, high elevation habitat (Leslie and Schaller 2009). Exterior morphological adaptations include relatively short legs and neck, small ears, dark-pigmented and unwrinkled skin, dense woolen pelage with developed arrector pili muscles, and a low surface area to volume ratio (Leslie and Schaller 2009). Internal adaptations include small pulmonary arteries, non-functional sweat glands, lack of preorbital glands and lachrymal fossa, smaller rumen and omasum, relatively expansive thoracic capacity and trachea, and more numerous but smaller sized red blood cells compared to cattle (*Bos taurus*) (Schaller 1998, Leslie and Schaller 2009). They have a short, broad tongue with extensive cutinized papillae that allow for foraging on brittle, senescent plants and tall grasses (Leslie and Schaller 2009).

Breeding

Female yaks typically become reproductively mature at 3-4 years (Fig. 2), but the timing is dependent upon body condition (Wiener et al. 2003). Peak reproduction occurs at 5-6 years (Fig. 2) and begins tapering off after 9 years, although wild yaks may live 15-20 years (Leslie and Schaller 2009). Mating occurs in the summer and calves are born between April and June of the following year, depending on elevation and associated seasonal food availability (Leslie and Schaller 2009). Yaks experience 1-4 estrus cycles per year but 75% of reproductively mature females conceive during their first cycle and gestation is 258–270 days (Leslie and Schaller 2009). Females only produce one calf per two or three years but can produce one calf per year with sufficient forage quality and quantity (Wiener et al. 2003). On average, 5-10% of pregnancies are prematurely aborted for unknown reasons (Wiener et al. 2003).

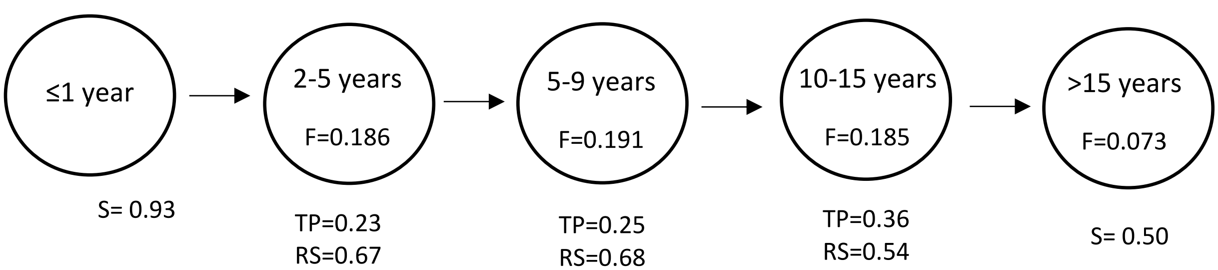

Figure 2. Stage-based wild yak life-cycle model with survival and fecundity rates. Survival is separated into transition probability (TP) and probability of remaining in stage (RS).

<u>Food</u>

Diet and Foraging

Wild yaks are non-selective grazers (Fig. 3; Liang et al. 2017) and ruminants (Leslie and Schaller 2009), which allows them to extract the maximum amount of carbohydrates from the cellulose they eat (Wiener et al. 2003). Their diets consist mostly of grasses in the Genus: *Stipa*

52%, *Kobresia* 4%, and *Carex* 14%, but also other grasses 4%, mosses 4%, herbaceous vegetation 12%, and dwarf shrubs 10% (Leslie and Schaller 2009). Alpine vegetation has relatively low nutritional quality and is scarce in early spring and winter (Awasthi et al. 2003) but yaks eat plants in proportion to their availability (Leslie and Schaller 2009).

Yaks migrate seasonally with weather cycles to access land at peak forage quality and abundance (Leslie and Schaller 2009). Wild Himalayan ungulates, including yaks, Tibetan argali (*Ovis ammon hodgsoni*), blue sheep (*Pseudois nayaur*), chiru (*Pantholops hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), and kiang (*Equus kiang*), partition resources along elevational gradients with limited competition because of variation in diet and feeding methods (Schaller and Binyuan 1994, Awasthi et al. 2003). Yaks forage non-selectively on a variety of plants in open environments, which allows them to congregate in herds of hundreds of individuals (Schaller and Binyuan 1994). Alpine meadows have the highest availability of standing-plant biomass (Berger et al. 2014) with the lowest ammonia nitrate levels (Wiener et al. 2003), relative to steppes and deserts. However, the growth cycles and species of vegetation in each habitat type are different, so yaks allocate time accordingly to optimize feeding efficiency (Schaller 1998). Food intake is negatively correlated with increased temperatures; the highest food intake occurs at or below -30°C, possibly to counteract the lower nutritional quality of plants in the winter (Wiener et al. 2003). In the spring and summer, yaks move to higher elevation steep slopes to eat the newly exposed vegetation once the snow and ice recede (Leslie and Schaller 2009). In the fall and winter, they move to lower elevation valleys, where resource competition with domestic ungulates frequently occurs (Buzzard and Berger 2016).

Figure 3. Wild yak (*Bos mutus*) grazing on senescent alpine grasses in the Himalayas.

Nutrient Intake and Requirements

In winter and early spring, wild yaks' diets are vitamin and mineral deficient; specifically, domestic yak (*Bos grunniens*) dietary profiles suggest that sodium, copper, and molybdenum are lacking (Leslie and Schaller 2009). Furthermore, only about 6% of their diet from October to May includes protein (Leslie and Schaller 2009). Wild yaks have been observed surrounding nutrient-rich springs and seasonal pools or eating snow to obtain water and minerals (Leslie and Schaller 2009). Endogenous purine derivative excretions in yaks are 60% less than in cattle and buffalo (*Bubalus bubalis*), possibly allowing them to fast for longer periods, which may be an adaptation to relatively low nutrient availability (Wiener et al. 2003). Additionally, they may be able to sequester more nitrogen in their rumen than other cattle, thus requiring lower daily intake (Wiener et al. 2003). Yaks require about 460.2 kilojoules of metabolizable energy per kilogram body weight per day for body maintenance (Wiener et al. 2003). Volatile fatty acid (VFA) production, a metric of energy in yaks, is higher when forage is premature or fresh and low when forage is wilted or dried (Wiener et al. 2003). Yaks produce high quantities of VFAs relative to other ruminants and production also increases with age (Wiener et al. 2003). This allows yaks to utilize more energy from plants and reduces the total biomass they must consume daily (Wiener et al. 2003).

Yaks have smaller rumen than other ruminant species, therefore requiring lower food quantities relative to their body size (Wiener et al. 2003). Although food consumption is sex, size, age, and environmentally-dependent, yaks' daily intake averages 18-25kg in summer and 6-8kg or less in winter (Wiener et al. 2003). Two to three-year-old yaks consume approximately 100-130 grams of dry matter per kilogram of their body weight daily and the amount typically increases with age (Wiener et al. 2003). Alpine steppe habitats only provide about 80-160 kilograms of dry matter per hectare, while alpine meadows may produce up to nine times more (Leslie and Schaller 2009). Lactating female yaks require more nutrients than non-lactating females and males (Wiener et al. 2003). However, increased availability and consumption of food is negatively correlated with digestibility (2.9-6.8% lower) and lactating females are less efficient in allocating food-energy to milk production than cattle (Wiener et al. 2003).

Cover

Habitat

Wild yaks most commonly inhabit Himalayan alpine meadows from 4500-6100m but move seasonally into alpine steppe or high cold desert (Buzzard and Berger 2016), which comprise 45%, 29%, and 14% of the Tibetan Plateau's total land cover, respectively (Leslie and Schaller 2009). They previously inhabited elevations near 3200m before pastoralists moved onto the land but higher frequency human-wildlife conflict has displaced them onto higher elevation habitat (Schaller and Wulin 1995). For example, the number of yaks observed in the Aru Basin decreased by 54% from 1990 to 1992 after pastoralists moved onto the land (Schaller 1998). In the Chang Tang Reserve, yaks select partially glaciated mountains with alpine meadows, alpine steppe during its 2–3 week "lush" period, and stream banks (Schaller 1998). Females and young typically live in separate herds from males at the upper limits of the suitable elevation range (Berger et al. 2014). At these locations, there are shorter ice-free periods and lower forage quality and availability. Alpine meadows, deserts, steppes, and valleys are dominated by grasses, sedges, small shrubs, and forbs (Awasthi et al. 2003), all of which comprise wild yak diets (Leslie and Schaller 2009). Mean annual temperatures range from 0 to -6°C, but winter temperatures can be lower than -40°C (Liang et al. 2017) and yaks' thermal neutral zone is estimated between -5 and 14°C (Wiener et al. 2003). Annual precipitation within the Chang Tang averages 100-300mm and there is minimal surface water availability (Buzzard and Berger 2016). Yaks are adapted for living in high elevation environments but air temperature has the most potential impact on their survival relative to precipitation and altitude (Wiener et al. 2003).

Distribution

Wild yaks occur within the northern Tibetan Plateau (Fig. 4), predominantly in China but some small populations may exist in northern India. Populations used to extend into Nepal and Afghanistan as well but are now extirpated (Liang et al. 2017). Within the Chang Tang Reserve (300,000km^2), yak distribution is divided into three sections: the southern, eastern, and western (Fig. 5; Schaller 1998). Yaks have been extirpated from the southern portion (24% total area), there are few remaining in the eastern (5% total area), and the majority remain in the western (71% total area) (Schaller 1998).

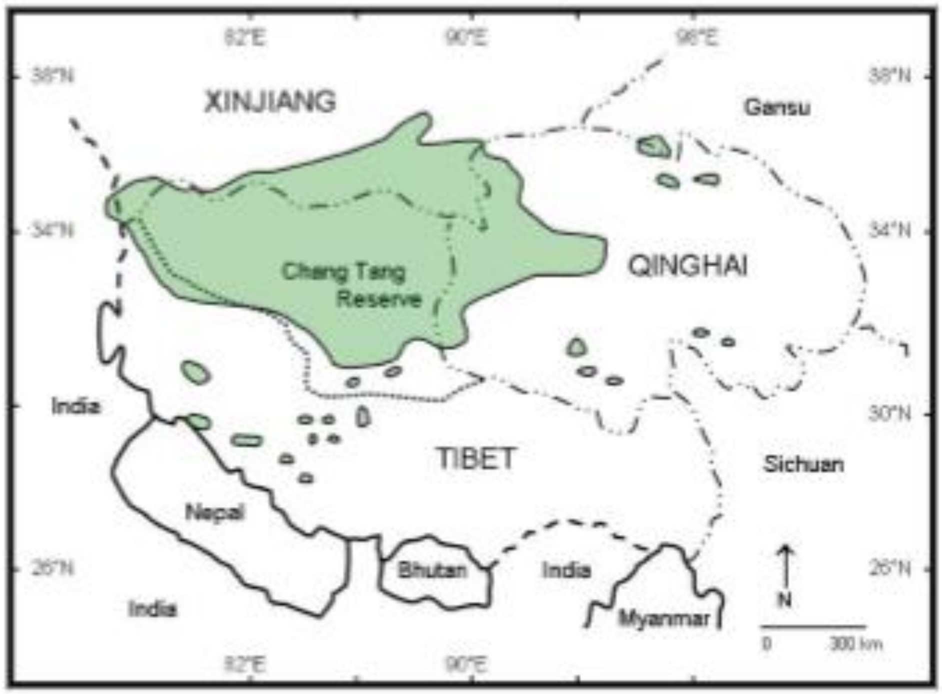

Figure 4. Wild yaks' (*Bos mutus*) entire remaining range is confined to the Tibetan Plateau. The largest population, approximately 7,000 of the 10,000 extant individuals, live within the Chang Tang Reserve of northwest Tibet (Leslie and Schaller 2009).

Wild yaks have clumped and seasonally-dynamic distributions (Leslie and Schaller 2009). They are non-migratory but capable of making long-distance, unpredictable movements, usually to avoid humans (Leslie and Schaller 2009). Space requirement estimates are highly variable in the scientific literature; individual yaks may require approximately 13km^2 (Schaller 1998) but yaks have frequently been observed in herds as dense as 1.5 individuals per 1km^2 (Leslie and Schaller 2009). Males and females' distributions vary slightly because females inhabit higher elevation, steeper slopes than males on average (Buzzard and Berger 2016). Female distribution is largely determined by nutritional requirements for reproduction and lactation and presence of potential predators (Berger et al. 2014).

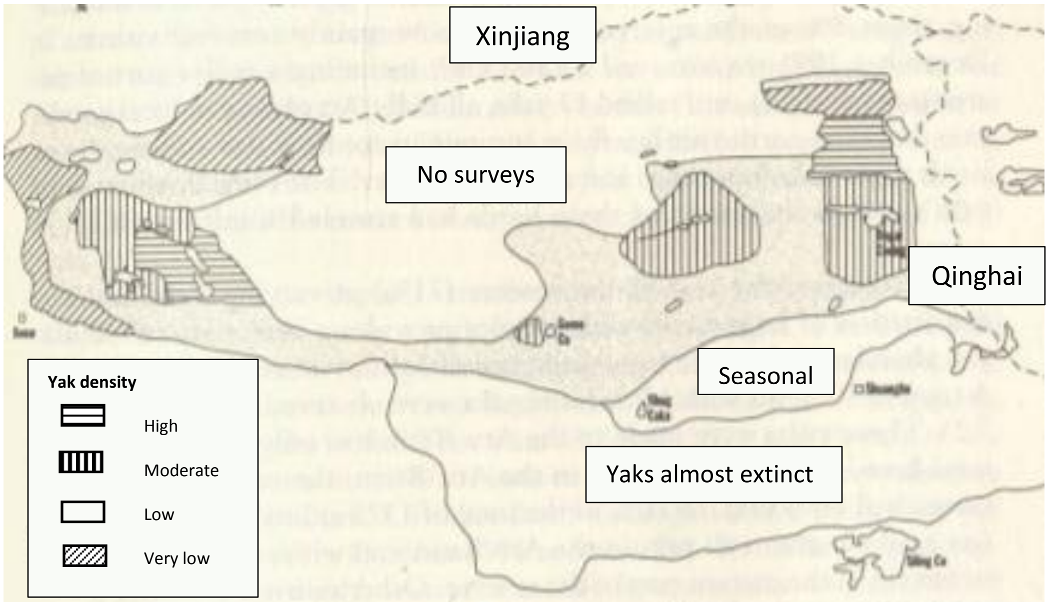

Figure 5. Wild yak (*Bos mutus*) distribution is divided into three major sections within the Chang Tang Reserve, China. Yak populations within these sections are variable because they experience different climatic conditions, resource competition, and human-wildlife conflicts (Schaller and Binyuan 1994).

Wild yaks, like other Bovids, have tend-bond polygynous mating systems which means that one male guards and mates with a group of females (Berger et al. 2014). During the rut (September), males wander alone in search of sexually mature females before returning to their male-only herds (Berger et al. 2014). During this time, males may be especially vulnerable to poaching or other threats (Schaller and Binyuan 1994). In the Chang Tang, calves are usually born between May and June during the daytime (Leslie and Schaller 2009). While females give birth, they isolate themselves from the herd, but once young are mobile (about 10-30 minutes after birth) they rejoin (Leslie and Schaller 2009). Distribution of females with young shifts towards the wettest, steepest available habitat to ensure optimal nutrition and predator avoidance (Leslie and Schaller 2009).

Predator and Weather Defense

Yaks have evolved to survive in cold climates; they become distressed at habitat below 3200m elevation and have been observed wading in icy water to thermoregulate on summer days (Schaller 1998). Cover is scarce on the Tibetan Plateau, with no vegetation sufficiently tall or widespread to provide camouflage or thermal benefit to adult yaks. Rather, wild yaks congregate in large herds, often with hundreds of individuals (Schaller 1998). Herd size depends on sex, season, and geographic area (Leslie and Schaller 2009). In the Chang Tang, male herds average 1-7 individuals but female herds often include 80-100 or more individuals (Leslie and Schaller 2009). Female herds include young of year and yearlings and occur at higher elevation as a possible predator avoidance method (Berger et al. 2014). Non-human depredation on wild yaks is rare, except on young or weakened individuals; Tibetan brown bear (*Ursus arctos pruinosus*) feces contained about 0.4% wild yak and wolves' (*Canis lupus*) feces only contained 0-10.4% (Schaller 1998, Leslie and Schaller 2009). However, group members form a circle around calves with adult males on the outermost edges to defend against perceived threats (Leslie and Schaller 2009). Male yak remains are disproportionately discovered in the Chang Tang and across other nature reserves in China, which indicates that they may be more susceptible to poaching or depredation by wolves and bears than females (Schaller and Binyuan 1994).

CONSERVATION NEEDS

Ecological

Resource Competition - There are 140 wild plant species in the alpine Himalayan ecosystem but only 13, mostly grasses and sedges, are considered palatable and common in ungulate diets (Awasthi et al. 2003). Wild yaks feed primarily on grasses, sedges, herbaceous plants, and dwarf shrubs, but will consume mosses and lichens in the winter (Leslie and Schaller 2009). Alpine meadows, which have the highest abundance and diversity of grasses and sedges, are selected by wild yaks and attract domestic ungulates as well (Leslie and Schaller 2009). Wild yaks frequently experience habitat overlap and competition with domestic yaks in the lower elevation portions of their range in the Chang Tang Reserve (Berger et al. 2014), which may also contribute to disease transmission (Wiener et al. 2003). Wild yaks have limited tolerance of human presence and often migrate away from their seasonal habitat if disturbed (Harris 2007). This disrupts their seasonal migration patterns which are essential for obtaining adequate fat and nutrient stores to survive high elevation climatic conditions (Leslie and Schaller 2009). Typically, male yaks inhabit lower elevations than females (Berger et al. 2014) so competition with domestic yak is a stronger factor in males' survival. However, because females live at higher elevation habitat and have larger herd sizes on average, there is intraspecific competition for resources at higher elevation (Berger et al. 2014). Naturally, ungulates in the Tibetan Plateau partition resources along the elevational gradient based on space needs and digestive capabilities (Leslie and Schaller 2009). In the Aru Basin (2,300km^2) of the Chang Tang Reserve, there were an average of 1.9 ungulates per square kilometer, but competition was minimal because of species-specific feeding strategies (Schaller and Binyuan 1994). For instance, wild yaks are non-selective grazers, so they consume all parts of a relatively wide variety of plants but do not decimate any one type (Schaller and Binyuan 1994). Increased density of domestic ungulates in these areas puts strain on the balance of resource allocation (Fox et al. 2003). In the winter months, available vegetation is further reduced (Awasthi et al. 2003) so both male and female wild yaks move to lower elevation, where domestic yaks are prevalent. Currently, wild yaks' range has been diminished to relatively small alpine meadows (Leslie and Schaller 2009).

Demographic - Wild yak populations are skewed towards adults because of continued low recruitment in much of their range, including the Chang Tang Reserve (Leslie and Schaller 2009). In 1990, young of the year made up only 6.7% of observed yak herds in the Aru Basin and even less in surrounding areas (Schaller and Binyuan 1994). Female yaks may only reproduce every two years and many young are depredated or experience other fatal circumstances (Schaller and Binyuan 1994, Buzzard and Berger 2016). During 1985, a snow storm caused complete loss of one year's offspring (Schaller and Binyuan 1994). In 1992, young only comprised 1% of the total yak population and only one yearling was observed in the Aru Basin, which suggests two consecutive years of reproductive failure (Schaller and Wulin 1995). Furthermore, wild yak herds consist of 1/3 more females than males, possibly because the lower elevation male habitat is more easily accessed by pastoralists and poachers (Schaller and Binyuan 1994).

Climate Change - Climate change has serious implications for nearly all species on earth, but especially mountain-dwelling species (Aryal et al. 2014). Higher frequency and intensity weather events may alter natural selection processes, quickly shift distribution of available food and suitable habitat, and lead to mass extirpations or extinctions (Wu et al. 2017). Severe snowstorms and other weather events can cause sudden, widespread mortality which may take generations from which to recover (Schaller and Binyuan 1994). Furthermore, temperatures are predicted to double in some Trans-Himalayan areas by 2161 (Aryal et al. 2014). Reduced average snowfall and increased mean annual temperatures are restricting agricultural land availability. Available land at higher elevation is subject to harsh climatic conditions and has relatively low productivity, thus forcing pastoralists to spread out across a larger land area in order to achieve the same level of subsistence as in past decades (Aryal et al. 2014). Higher temperatures and less snow cover also cause some grass and shrub species to desiccate before reproducing, which leads to lower food availability and animals must subsequently forage on cultivated or grazed land (Aryal et al. 2014, Liang et al. 2017). Climate change effects are estimated to reduce wild yak habitat by an additional 30% in the next 50 years (Wu et al. 2017). Conversely, glacial recession may increase access to higher elevation land for wild yak habitat in future years (WCS 2019). If higher elevation habitat does become available, it will likely also be utilized by pastoralists, thus increasing the risk of human-wildlife conflict (WCS 2019). Furthermore, if wild yaks range expands in a future warmer, wetter climate (Wu et al. 2017), populations may become more vulnerable to fragmentation.

Sociocultural and Economic

Subsistence Culture **-** Sociocultural threats to wild yaks include increased human land use which has led to reduced available habitat for wild yak and competition with domestic ungulates (Schaller and Wulin 1995, Buzzard et al. 2010). In the 1950s, Tibetans, who had traditionally lived sustainably without significant alteration to land or wildlife in Chinese nature reserves, were prohibited from inhabiting and grazing livestock (Harris et al. 1999). When Kazakhstanis from Xinjiang moved into these areas, the long-established relationship between humans, land, and wildlife was disrupted, and, even after these groups left, traditional systems were not restored (Harris et al. 1999). In the southern 24% of the Chang Tang Reserve, there has been an increase to 1.5 million head of livestock since the 1960s and wild yak have been almost completely extirpated (Schaller and Wulin 1995). Furthermore, gold-mining and increased wealth since the 1980s, which have led to improved accessibility via roads and more commercial market hunting, have led to significant population decline and habitat fragmentation (Harris et al. 1999).

Yaks are culturally and economically important sources of several food items, dung for fuel, clothing and tool-making materials, and financial capital (Tsering et al. 2006). Although legally protected, pastoralists still partially rely on wild yaks for subsistence through hunting and parts trading (Fox et al. 2004). Domestic yaks may assimilate into or be displaced by wild herds; occasionally, domestic females are lost to wild herds after sometimes violent confrontations between wild males and pastoralists (Tsering et al. 2006). Under these rare circumstances, humans have participated in retaliatory killing of wild yaks (Tsering et al. 2006, Buzzard 2011). However, pastoralists cannot cease movement of their domestic herds because mobility ensures the long-term health of rangeland systems by reducing overgrazing (Richard 2000). These rangeland systems are essential for high-elevation herbivorous organisms, including chiru, Tibetan gazelle, kiang, Tibetan argali, and blue sheep, which co-inhabit the steppes and alpine meadows where yaks are found (Schaller and Binyuan 1994, Fox et al. 2004). Thus, consideration and careful planning is needed to maintain a balance between wild ungulate habitat needs and domestic yak space use (WCS 2019).

Genetic Dilution - Domestic yaks are more frequently hybridizing with wild yaks because of the increase in number of pastoralists, size of their herds, and their widespread distribution spanning into elevations above 4000m (Richard 2000). In some areas, wild yaks are protected for use in breeding programs to introduce desirable traits into domestic herds (Buzzard 2011). Hybridization diminishes important characteristics, including cold-tolerance, relatively large body size, digestive adaptations (i.e., smaller rumen), and a variety of genetically-inherited instincts (Wang et al. 2011). This is important because unlike domestic yaks, wild yaks require certain characteristics, such as an efficient metabolism to process low-quality available forage, especially during winter (Wang et al. 2011). Furthermore, yaks’ generation length is approximately ten years (Buzzard and Berger 2016) so it would take many generations to minimize the effects of hybridization in the gene pool if action was taken now.

Legal

National Protection - Wild yaks are listed in Convention on International Trade in Endangered Species (CITES) Appendix 1 as a Class 1 protected species in China, which means that trading whole individuals or any of their parts or derivatives is prohibited (Buzzard and Berger 2016). While theoretically this classification should adequately protect wild yaks, there is little enforcement of wildlife-related regulation in the remote areas inhabited by yaks to prevent habitat loss, poaching, and trade (Schaller and Wulin 1995, WCS 2019). However, wild yaks receive more protection in India, where they are covered as a Schedule 1 species under The Wildlife (Protection) Act of 1972 (No. 53 of 1972) (Buzzard and Berger 2016). They are also listed as vulnerable with decreasing population trends on the IUCN Red List (Buzzard and Berger 2016). Yaks should receive further protection to eliminate poaching and reduce habitat degradation caused by pastoralists and livestock (WCS 2019).

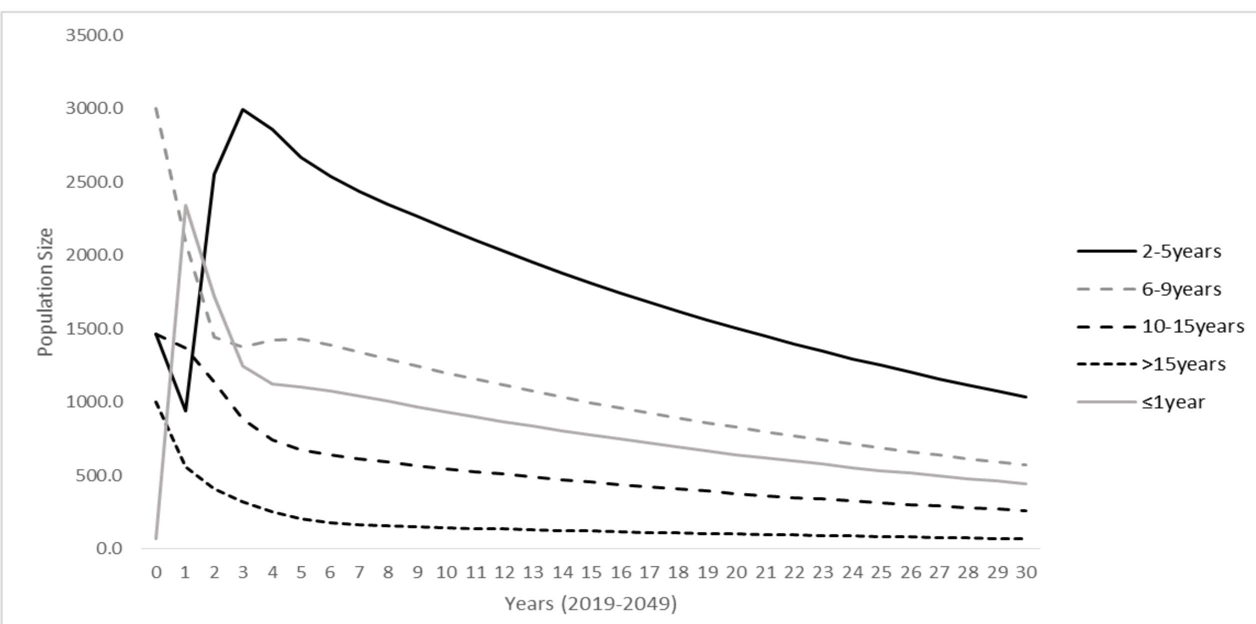

Figure 6. Wild yak (*Bos mutus*) population trends by age group in the Chang Tang Reserve, China. These trends were created assuming 7,000 individuals and they estimate population dynamics if conservation concerns are not addressed over the management timeline.

Statement of Need

As described above, a variety of ecological, sociocultural, economic, and legal factors justify the management of wild yaks in the Chang Tang Reserve. In the face of climate change, which affects mountainous ecosystems up to twice as fast as other ecosystems (Aryal et al. 2014), wild yak habitat will be further reduced (Schaller and Wulin 1995). The effects of climate change, combined with the growing and expanding human population, will push wild yaks into less suitable habitat (Schaller and Wulin 1995, Wu et al. 2017). The expansion of pastoralists onto previously inhospitable land will cause stronger competition between domestic and wild yaks (Harris et al. 1999), leading to potential human-wildlife conflict, hybridization, food scarcity, and reduced survival of wild yaks (Fig. 6; Scaller and Wulin 1995). However, cultural heritage and subsistence living make it unreasonable or impossible to place strict preservation management on the Chang Tang Reserve (WCS 2019). Coexistence between humans and yaks is possible if proper management is implemented to conserve native grasslands for food and preserve wild genetic characteristics (Fox et al. 2004). A plan to create buffer zones around wild yak habitat was proposed by the Wildlife Conservation Society in conjunction with several Tibetan agencies, including the Chang Tang National Nature Reserve Management Bureau of the Tibetan Autonomous Region, the Tibetan Academy of Agriculture and Animal Husbandry Sciences, the Tibetan Forestry Bureau, and Nyma County Forestry Bureau, but has not yet been implemented (WCS 2019). A management plan as such, that considers the most imminent threats to wild yak populations while accounting for local peoples' needs, is necessary for long term success.

Goal: Restore wild yak population to 1995 estimate (Schaller and Wulin 1995) to support traditional subsistence use by locals in thirty years in the Chang Tang Reserve, China.

Objective 1 - Increase population of annually fertile females by 50% in fifteen years.

Action 1.1: Conduct additional research to improve understanding of female fertility. Elasticity and sensitivity matrices suggest that yak females ages 2-5 are the most sensitive to changes in survival and fecundity rates. Thus, life history characteristics within the 2-5 age class should be further analyzed. Aerial surveys will be used to observe population dynamics, including population size, density, and sex and age ratios (Kuzyk et al. 2018). Surveys will be focused on higher elevation, steep slopes where female-offspring herds primarily exist (Leslie and Schaller 2009). Furthermore, fecal sample analyses will be conducted to identify age-based dietary component variation (Morgia and Bassano 2009). These data will allow managers to incorporate optimal forage types when action 1.3 is implemented. Wild yak data are relatively difficult to collect because of their remote habitat and fleeing behavior (Schaller 1998), so a plausible goal would be to complete a minimum of five peer-reviewed articles within the thirty-year management timeline. The research will provide a scientifically-founded justification for further management actions and ensure that the current proposed actions are appropriate given newly acquired information.

Action 1.2: Create buffer zones with barriers around domestic yak grazing land to reduce resource competition and hybridization (WCS 2019). In 1973, the National Parks and Wildlife Conservation Act protected lands and created buffer zones to promote wildlife conservation in Nepal (Heinen and Shrestha 2006). The Chang Tang Reserve contains a major portion of the vegetated land on the Tibetan Plateau (Fox et al. 2008); thus, use will be allowed to continue with strict regulations, similar to Nepal's buffer system (Heinen and Shrestha 2006). Permits will be issued to allow use for purposes that do not directly or indirectly lead to take, direct human contact, or domestic-wild yak contact. No temporary or permanent residency will be allowed within the buffer zones because wild yaks are relatively intolerant of human presence (Schaller 1998). The buffer zones will be approximately 25% the size of the land area occupied by the domestic herd within to maintain separation of wild and domestic yaks while limiting over-grazing (Richard 2000), Knitted propylene mesh fencing materials will be distributed to cooperating pastoralists to demarcate buffer zones and may be moved seasonally to maintain livestock and ecosystem health (Richard 2000).

The buffer system could potentially reduce the total forage availability for domestic yaks and may require herdsmen to provide additional fodder for their livestock throughout the year. It may also cost pastoralists a loss of goods and trade opportunities if milk or meat production are limited by lack of food (Wiener et al. 2003). Although fencing materials will be provided for the landowner and could be moved as needed, they will cost time to set up. If fencing is widely distributed across the landscape, it may also disrupt migration of other Himalayan megafauna, such as Tibetan antelope (*Pantholops hodgsonii*) (Fox et al. 2009). Furthermore, prohibition of permanent residency may be an impossible requirement as human populations increase and climatic changes open more land for pasture (WCS 2019).

Action 1.3: Provide supplementary food plots at high elevation where resources are scarce. Female yaks and offspring congregate in herds at higher elevation than males (Leslie and Schaller 2009), so this food source will be easily accessible for them. To maximize efficiency, the areas most suitable to support native perennial vegetation based on current and future estimated climatic conditions will be determined (Awasthi et al. 2003, Aryal et al. 2013, Wu et al. 2017). Once planted, food plots should not require further care beyond annual monitoring (Brummer 2008). A majority of *Stipa*, *Kobresia*, and *Carex* will be incorporated within food plots because they are the natural primary yak food sources (Leslie and Schaller 2009) but monoculture will be avoided in plots. Monoculture food plots will decrease the diversity of the natural grassland community and lead to soil erosion, which will limit the future capacity of the land to support vegetation (Pohl et al. 2009). Monoculture will also contribute to yak malnutrition, which decreases survival and reproduction (Wiener et al. 2003, Zi et al. 2003). Calving rate increased by over 20% when two or more feed types were given to domestic yak between December and April (Zi et al. 2003). The onset of puberty, estrus frequency, and fecundity rate also increased with a mixture of food supplementation (Wiener et al. 2003, Zi et al. 2003). Adequate access to nutrition prior to the winter months will ensure yaks are capable of supporting fetuses and supplying milk to newborn calves in the early spring, thus increasing calf survival (Wiener et al. 2003). Incorporation of salt blocks near food plots will further increase reproductive success and winter survival (Wiener et al. 2003) by providing necessary minerals which may be lacking in senescent plants. Minerals supplied through salt blocks increased domestic yak milk production by an average 15.5% (Wiener et al. 2003).

No Action: Wild yaks have relatively low recruitment and productivity (Wiener et al. 2003). If competition and hybridization are not reduced, unique genetics will be lost and survival and reproduction will be significantly reduced (Wang et al. 2011, Berger et al. 2014). Without food supplementation, wild yaks will have to travel to lower elevation more frequently to obtain food and subsequently interact with humans and livestock more often (Schaller and Wulin 1995). This may lead to negative consequences, including hybridization, resource competition, inadequate nutrition, lower recruitment, disease transmission, and human-wildlife conflicts.

Disease contraction may cause sudden, widespread mortality in wild yak populations (Roth et al. 2003), which may take generations to mitigate (Buzzard and Berger 2016).

Final Courses of Action: Actions 1.1 will be implemented immediately and continued throughout the management timeline until completed. Action 1.2 will not be implemented and action 1.3 will be implemented within the first five years and potentially throughout the fifteen years.

Rationale: Action 1.1 will be initiated within the first year and continued throughout the fifteen years or until complete because it will take significant time to collect data and publish the articles. Action 1.2 will not be implemented initially because it may lead to public resistance, economic loss, or disruption of migration. However, it may be implemented after fifteen years if action 1.3 has not been successful. Action 1.3 will be initiated within the first five years, but its continuance in years 6-15 is pending assessment.

ASSESSMENT PROTOCOL: Upon completion of action 1.3, success will be assessed by calculating the percentage of females in the Reserve that are reproducing every year after fifteen years. As part of the research conducted (action 1.1), the total number of mature females will be counted and unique markers assigned to identify individuals (ASM-ACUC 1998). Aerial surveying is the most efficient way to locate female herds, but will be supplemented by on-foot surveys to ensure males are not included in counts (Schaller and Wulin 1995). Radio collaring capable of collecting vital rates will be used to individually mark and track female yaks (ASM-ACUC 1998). By tracking individuals and monitoring their vital rates for at least three years, managers will be able to determine whether female reproduction has increased (Wiener et al. 2003). Success will be measured using a comparison of paired proportions test with the initial percentage of females reproducing yearly (Schaller and Wulin 1995) and the percentage reproducing yearly fifteen years later. By the third year, at least a 9% increase must occur to be considered successful.

If the population of annually fertile females has not increased by 50% after fifteen years, management actions will be adjusted. Managers will quantify any change in reproduction and determine alternative actions if necessary. If reproduction has increased, but at a slower rate than expected, the number of food plots may need to be increased or action 1.2 may need to be implemented. However, if reproduction has remained the same or decreased, at least one peer-reviewed scientific article will be published identifying other possible reproductive influences within five years after the final assessment. If lack of funding, elusiveness of the study species, or insufficient time to collect data lead to failure (Schaller 1998), more than fifteen years may need to be allotted to secure funding, complete thorough research, and implement subsequent management actions. Funding may be available through the Wildlife Conservation Society or local government agencies.

Objective 2 - Increase connectivity between the Reserve and other fragmented portions of wild yaks' distribution in China by 25% within ten years.

Action 2.1: Provide adequate corridors over roadways or around settlements to facilitate maintenance of life processes (i.e. foraging, mating, and dispersal) (Schumaker 1996). Above-ground corridors need to be structurally-capable of withstanding the weight of wild yaks (350-1,200kg each) as they travel in large herds (Leslie and Schaller 2009). These should consist of reinforced steel with soil and vegetation covering the top to increase inconspicuousness and food availability (Adams et al. 2017). Corridors at ground level need to be sufficiently expansive (at least 400m wide) to accommodate yak travel without causing bottlenecks towards human or livestock conflicts (Adams et al. 2017). Initial connectivity will be quantified through geographic information systems (GIS) mapping (Zhao et al. 2014). Habitat suitability between patches will be increased by planting forage plants (see action 1.3) and limiting human presence during optimal yak travel seasons (summer breeding and spring food scarcity) (NRCS 1999, Leslie and Schaller 2009); this will facilitate migration between patches. Corridors will be especially important during the rut to increase mating opportunities and population heterozygosity (Berger et al. 2014). Additionally, connecting habitat fragments may allow yaks to recolonize the southern 24% of their range from which they are currently extirpated (Schaller 1998, NRCS 1999). Initial focus will be put on connecting patches near the Chang Tang Reserve (Schaller 1998) but eventually, the outermost patches will be linked to avoid both deterministic and stochastic factors causing population declines.

Action 2.2: Enforce corridor border restrictions during ecologically significant time periods, such as breeding season and when food is particularly scarce (Leslie and Schaller 2009). Yaks migrate away from human disturbance, which may decrease time allocated to foraging or searching for mates (Leslie and Schaller 2009). Physical barriers cannot be implemented to deter humans because they will not facilitate wildlife movement. Thus, law enforcement will be required to prohibit access of these corridors by the public to allow yaks to move freely. Existing local law enforcement will add the borders to current patrol routes and they will patrol on foot to minimize noise and further yak disturbance. At least one official will be assigned a full-time post near each corridor to answer public comments and questions, while removing any disruptive individuals from the premises. However, preventing all access to corridor lands will be difficult or impossible; it may be too expensive to enlist enough law enforcement officials to adequately protect all the borders.

No Action: If corridors are not established, hybridization may occur, which leads to reduced survival and reproduction (Wang et al. 2011). If habitats are connected, there are fewer edge effects and more available land for all individuals to access (Kuemmerle et al. 2011). There are at least twenty wild yak habitat fragments outside the Reserve (Schaller 1998) which may be vulnerable to metapopulation extinction via limited resource availability, hybridization, and poaching if not connected (Kuemmerle et al. 2011).

Final Course of Action: Action 2.1 will be implemented within ten years. Action 2.2 will not be implemented.

Rationale: Action 2.1 will be implemented but not supplemented by action 2.2 because of lack of economic feasibility. Action 2.1 will contribute to long term management success by increasing emigration and immigration between populations and increasing mating opportunities and heterozygosity, while also increasing suitable habitat availability.

ASSESSMENT PROTOCOL: Habitat connectivity will be assessed by identifying habitat requirements that allow yak migration and determining whether those have been met by action 2.1 within ten years. Habitat will be defined by the presence of habitat suitability parameters (i.e., food availability, lack of human disturbance). The land between previously fragmented habitats will also be categorized using habitat suitability indices (Kuemmerle et al. 2011, Zhao et al. 2014). Furthermore, camera traps will be used to determine whether yaks are using established corridors to move between patches (Erb et al. 2012, Adams et al. 2017). Management will be considered successful if yaks are migrating between patches and new GIS maps demonstrate a 25% increase in connectivity compared to original maps.

If connectivity has not been increased by 25%, reasons for failure will be identified. Local cooperation or funding for corridors may need to be increased (WCS 2019). As pastoralists gain wealth, they continue to acquire land and expand their herds, which makes it more difficult to preserve undisturbed habitat for wild yaks (Schaller and Wulin 1995, WCS 2019). Corridors need to be relatively undisturbed to promote wild yak use because they will flee in the presence of humans (Schaller 1998). Thus, pastoralists must agree not to use these lands and may lose potential grazing land or associated profits (WCS 2013). To mitigate failure, corridors may need to be expanded or habitat suitability within may need to be increased (Kuemmerle et al. 2011). If necessary, additional funding may need to be sourced from the Wildlife Conservation Society or other voluntary donors. Furthermore, corridor management will be installed as part of the educational components outlined in action 3.2.

Objective 3 - Increase landowner cooperation in wild yak conservation efforts by at least 75% within ten years.

Action 3.1: Design and implement surveys to determine the present knowledge of yak conservation needs and importance (Appendix A). Survey bias will be limited by asking simple, closed questions that do not include emotionally-charged words or phrasing. Demographic information will be asked at the end of the survey to detect possible correlations between cooperation or awareness and age, sex, income, or other variables (WCS 2013). Records will be kept with local individuals' names, contact information, and survey answers. Monetary incentives will be offered for cooperation to encourage long term conservation and management.

These incentives will also help to diminish possible effects of lower income lifestyle on land use and improve quality of locals' lives (Tsering et al. 2006).

Action 3.2: Facilitate public forums and grade school activities that educate locals. The pastoralist lifestyle is often passed down through family members (Fox et al. 2004), so it is important to target locals of all ages. For younger children, 5-12, education will be presented in the form of hands-on activities and games; older children, 12-18, may benefit more from a formal, lecture-style education; adults will be provided the opportunity to attend bi-monthly public forums and annual workshops (Appendix B) that focus on field methods and cost-benefit analyses of wild yak conservation and management (Wiener et al. 2003). Locals will be made aware that reducing wildlife-domestic conflict will indirectly increase profitability from dairy and meat products (WCS 2013); this is true because if diseases, such as Brucellosis, are spread, yak offspring mortality will increase and milk and meat production will decrease (Wiener et al. 2003). Brucellosis can be controlled via vaccination, proper herd management, sanitation, and dairy pasteurization but many livestock owners lack education on the symptoms or control methods (Holt et al. 2011). Complementary materials will be provided for participating locals (i.e. brochures, seeds, sanitary products) to encourage voluntary preventative and promotional actions. Signs will be posted near existing domestic grazing land and in cities to educate landowners and tourists on habitat sensitivity and conservation importance (Appendix C). Discussion with locals will keep managers updated on changing perspectives and successful management strategies.

No Action: The Tibetan Plateau is a remote area in China with harsh climatic conditions that make research and management difficult (Schaller 1998). Thus, local cooperation in implementing management strategies and conserving suitable habitat is important for long term success. If locals have negative perceptions of management or of wild yaks in general, or if their quality of life is relatively low (Tsering et al. 2006, WCS 2013), they may hinder the progress of managers. Furthermore, if pastoralists continue to move into higher elevations, they will push wild yaks onto less suitable habitat with frequent resource competition (Schaller and Wulin 1995, Buzzard et al. 2010).

Final Courses of Action: Action 3.1 will be implemented within years 1-3 and action 3.2 will be implemented in years 3-10.

Rationale: Action 3.1 will be implemented first to determine how much information needs to be distributed to the public (action 3.2). Action 3.2 will facilitate information sharing between scientists, managers, and locals, which is important for encouraging positive perspective development and willingness to cooperate.

ASSESSMENT PROTOCOL: Objective 3 will be considered successful if cooperation has increased by 75% within ten years. Managers will either verbally interview, distribute written surveys, or visually observe cooperation depending on landowner availability. If at least 75% of landowners are obeying corridor restrictions, maintaining food plots, and reducing domestic-wildlife conflicts to the best of their ability, management will be considered successful.

If objective 3 has not been met within ten years, managers will either decide to allow more time or adjust actions. It may take more than ten years for locals to accept and actively cooperate with proposed management, especially since many of the threats to wild yaks are rooted in Tibetan cultural practices (Fox et al. 2004). Scoping will be completed in forums and locals' advice will be considered if managers adjust the actions. Funding may be difficult to obtain because of the perceived potential for pastoralist money loss through the expansion of wild yaks onto suitable pasture lands (WCS 2013). If adequate funding is not available through the local government, funds from the United States may need to be loaned to the Chinese government.

Conclusion

This wild yak management plan for the Chang Tang Reserve could potentially increase wild yak populations above the carrying capacity (~85,000), but allowing locals' subsistence use will keep them below this threshold. Habitat fragments should be connected, supplemental food should be provided, and locals should be educated on the consequences of their pastoralist and subsistence cultures on the environment. Traditional practices can be continued if they are maintained at sustainable levels. Resource competition with domestic ungulates, habitat loss, hybridization, poaching, and parts trading are all threats to wild yak populations. By combining existing knowledge with models, a thorough set of actions and associated assessments have been developed. Implementing the finalized courses of action outlined in this plan will allow managers to reach the management goal of restoring wild yak populations to the 1995 estimate (Schaller and Wulin 1995) to support traditional subsistence use by locals in thirty years in the Chang Tang Reserve, China.

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Appendix A

Thirty-year Wild Yak (*Bos mutus*) Management Plan for the Chang Tang Nature Reserve, China

Survey Questions 2019

1. Are you familiar with wild yak (*Bos mutus*) conservation efforts in China? (Choose one)
    a. Yes
    b. No
    c. Unsure
2. Do you believe wild yaks are an important resource in China? (Choose one)
    a. Yes
    b. No
    c. Unsure
    d. Other (explain):
3. Have you noticed any changes in the number of people near or within the Chang Tang Reserve? (Choose best answer)
    a. Yes, there are more now than previous years.
    b. Yes, there are fewer now than previous years.
    c. No, there have not been any noticeable changes.
    d. Unsure
4. Have you ever experienced conflicts with wild animals within the Reserve? (Choose one and describe)
    a. Yes (explain):
    b. No
    c. Other (explain):
5. Do you temporarily or permanently reside within the Reserve? (Choose one)
    a. Yes
    b. No
    c. Unsure
6. How often to you travel to the Chang Tang Nature Reserve? (Choose best answer)
    a. Less than one time per year
    b. One-Five times per year
    c. More than five times per year
7. Which term best describes your lifestyle? (Choose best answer)
    a. Pastoralist
    b. Industrial Worker
    c. Merchant
    d. Food Service Worker
    e. Other

Appendix B

Public Forum and Workshops 2019

Thirty-year Wild Yak (*Bos mutus*) Management Plan

For the Chang Tang Nature Reserve, China

Topics Schedule

Workshop One: Understanding legislation: The do's and don'ts of land use on the Tibetan Plateau

- Forum One: Wild yaks: Natural history, threats, and management objectives
- Forum Two: Conservation versus preservation and the land ethic
- Forum Three: Sustainable use: How-to guide, benefits, and incentives
- Forum Four: Climate change observations and future preparations
- Forum Five: New wild yak data
- Forum Six: Feedback from management thus far and future considerations

Appendix C

Protect Wild Yaks!

The Tibetan Plateau is a sensitive habitat area

Please consider limiting disturbance by reducing travel and keeping livestock below 4,000m

Incentives available for cooperation.

Thank you for your help in conserving this vulnerable species!

Please Contact the Wildlife Conservation Society-China for more information.

(+86 (0)10 5207 1599)